10/688,397

INVESTOR IN PEOPLE

The Patent Office
Concept House
Cardiff Road
Newport
South Wales
NP10 8QQ

I, the undersigned, being an officer duly authorised in accordance with Section 74(1) and (4) of the Deregulation & Contracting Out Act 1994, to sign and issue certificates on behalf of the Comptroller-General, hereby certify that annexed hereto is a true copy of the documents as originally filed in connection with the patent application identified therein.

In accordance with the Patents (Companies Re-registration) Rules 1982, if a company named in this certificate and any accompanying documents has re-registered under the Companies Act 1980 with the same name as that with which it was registered immediately before re-registration save for the substitution as, or inclusion as, the last part of the name of the words "public limited company" or their equivalents in Welsh, references to the name of the company in this certificate and any accompanying documents shall be treated as references to the name with which it is so re-registered.

In accordance with the rules, the words "public limited company" may be replaced by p.l.c., plc, P.L.C. or PLC.

Re-registration under the Companies Act does not constitute a new legal entity but merely subjects the company to certain additional company law rules.

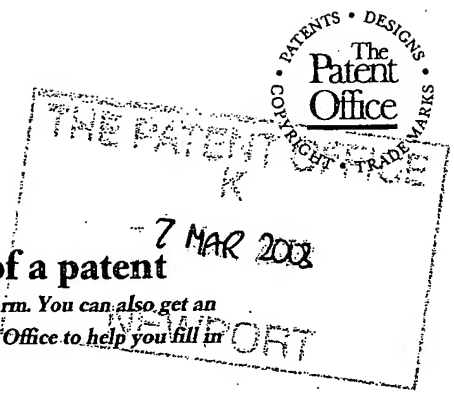
Signed Andrew Gerry

Dated 10 October 2003

10/666,397

Patents Form 1/77

Patents Act 1977
(Rule 16)



07MAR03 E790219-2 D01463
P01/7700 0.00-0305225.5

1/77

Request for grant of a patent

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)

The Patent Office

Cardiff Road
Newport
South Wales
NP10 8QQ

1. Your reference — 200309650-02GB2

2. Patent application number *(The Patent Office will fill in this part)* — 0305225.5

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

Hewlett-Packard Development Company, L.P.
20555 S.H. 249
Houston, TX 77070
USA

Patents ADP number *(if you know it)* 8557886001

If the applicant is a corporate body, give the country/state of its incorporation

4. Title of the invention — Method and Apparatus for Managing a Hierarchy of Nodes

5. Name of your agent *(if you have one)*

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

Robert F. Squibbs
Hewlett-Packard Ltd, IP Section
Filton Road, Stoke Gifford
Bristol BS34 8QZ

7563083001

Patents ADP number *(if you know it)*

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*
GB	0302410.6	3/2/2003

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*

a) any applicant named in part 3 is not an inventor, or
b) there is an inventor who is not named as an applicant, or

Yes

Patents Form 1/77

9. Enter the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document

Continuation sheets of this form	
Description	12
Claim(s)	7
Abstract	1
Drawing(s)	3 + 3

10. If you are also filing any of the following, state how many against each item.

Priority documents	
Translations of priority documents	
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	
Request for preliminary examination and search *(Patents Form 9/77)*	1
Request for substantive examination *(Patents Form 10/77)*	
Any other documents *(please specify)*	Fee Sheet

11. I/We request the grant of a patent on the basis of this application.

Signature R. F. Squibbs Date 4/3/2003

Robert F. Squibbs

12. Name and daytime telephone number of person to contact in the United Kingdom

Tony Judd Tel: 0117-312-8026

Warning

After an application for a patent has been filed, the Comptroller of the Patent Office will consider whether publication or communication of the invention should be prohibited or restricted under Section 22 of the Patents Act 1977. You will be informed if it is necessary to prohibit or restrict your invention in this way. Furthermore, if you live in the United Kingdom, Section 23 of the Patents Act 1977 stops you from applying for a patent abroad without first getting written permission from the Patent Office unless an application has been filed at least 6 weeks beforehand in the United Kingdom for a patent for the same invention and either no direction prohibiting publication or communication has been given, or any such direction has been revoked.

Notes

a) *If you need help to fill in this form or you have any questions, please contact the Patent Office on 08459 500505.*

b) *Write your answers in capital letters using black ink or you may type them.*

c) *If there is not enough space for all the relevant details on any part of this form, please continue on a separate sheet of paper and write "see continuation sheet" in the relevant part(s). Any continuation sheet should be attached to this form.*

d) *If you have answered 'Yes' Patents Form 7/77 will need to be filed.*

e) *Once you have filled in the form you must remember to sign and date it.*

Method and Apparatus for Managing a Hierarchy of Nodes

Field of the Invention

The present invention relates to a method and apparatus for managing a node hierarchy of nodes such as, for example, a key hierarchy used by a trusted platform for protecting sensitive data.

Background of the Invention

TCPA technology is specified in the TCPA specifications and described, for example, in the book "trusted computing platforms – tcpa technology in context"; Pearson (editor); Prentice Hall; ISBN 0-13-009220-7".

A trusted platform built according to today's TCPA specifications will incorporate a trusted platform subsystem typically comprising a Trusted Platform Module (TPM) in the form of a hardware chip separate from the main CPU, a Root of Trust for Measurement (RTM) formed by the first software to run during the boot process, and support software termed the Trusted platform Support Service (TSS) which performs various functions such as those necessary for communication with the rest of the platform. In a PC, the RTM will typically be founded upon BIOS instructions that cause the main platform processor to do RTM work; this set of instructions is called the Core Root of Trust for Measurement (CRTM) for convenience.

The RTM and associated measurement agents carry out integrity measurements (integrity metrics) on the platform at various stages and store the results in a measurement log in ordinary memory; however, a condensed summary is also stored in Platform Configuration Registers (PCRs) of the TPM.

In addition to the PCRs, the TPM comprises a processor and various cryptographic functions as well as memory for permanently holding secrets such as the private TPM endorsement key and the storage root key (SRK). With regard to the SRK, the TPM supports a Protected Storage mechanism in the form of a hierarchy (tree) of data objects the

root of which is the SRK; apart from the SRK that is permanently stored in the TPM (and not released from it), the tree can be stored outside of the TPM. When information in a node is used or revealed, the node is manipulated by the TPM. Each intermediate node object in the tree is encrypted by a key in the node object above it in the tree (the parent node), all the way back to the SRK root node. Each key has an associated authorisation value that must be presented to the TPM (or, more accurately, used in a protocol that proves knowledge of the value without revealing the value) before the TPM permits the key to be used. Intermediate nodes in the tree will always be keys but leaf nodes can be arbitrary data (though frequently they will also be keys, such as symmetric keys for use by application processes in protecting bulk data). Keys in the tree can either be "non-migratable" meaning that the private key is only known to the TPM, or "migratable" meaning that there is no guarantee about the origin and use of the private key.

Access to keys in the key hierarchy (and thus to the data protected by the keys) can be made dependent on the current state of the platform as indicated by the values held in the PCRs. The relevant TCPA functions are TPM_Seal and TPM_Extend which enable a TPM to conceal decryption keys unless the value of current PCR is the same as stored PCR values. This sealing process ("Seal") enables enforcement of the software environment (PCRs) that must exist before data can be revealed, and simultaneously provides a method of concealing data (because the TPM releases a decryption key) until that environment exists. Seal is therefore an access control that depends on the *previous* state(s) of a platform (represented in terms of PCRs). Seal permits the creator of data to dictate the software environment that must exist in a platform when the data is used

A trusted platform built according to today's TCPA specifications can be relied upon to store secrets, provide a platform identity, and reliably report the Operating System (OS) in a platform. Common operating systems cannot be relied upon to protect secrets once they have been revealed to the platform's software, nor to report on what has happened since the OS took control of the platform. This is because these OS's cannot be relied upon to reliably measure and store integrity metrics in the TPM's PCRs. It's not that common OSs can't measure and store integrity metrics, it's that they cannot protect themselves against subversion, so integrity metrics can't be trusted if they were stored after the OS was

loaded. One consequence of the lack of trustworthiness of the OS is that the sealing process described above has limited value in platforms with existing conventional OSs, because they cannot be relied upon to reliably measure and store integrity metrics in the TPM's PCRs.

Thus, current trusted platforms are limited because today's Core Root of Trust of Measurement (CRTM) is in a relatively unprotected BIOS chip, and because Operating Systems are insufficiently protected against subversion. Nevertheless, all functions that are provided by a TPM are fully protected, and if the platform's pre-boot environment (especially its BIOS Boot Block, acting as the TCPA Core Root of Trust for Measurement) is properly designed, all operations that executed before the OS can be faithfully recorded in the TPM's PCRs.

If the software on a platform is written to take advantage of the processing "rings" (levels of privilege) on processors (such as Intel processors), that software can use these rings to protect itself against subversion. A secure compartment-OS that is protected by virtue of these processing rings can dynamically create and destroy isolated software compartments. Applications then execute in isolated compartments, which protect the application from other applications, and visa versa. Each compartment provides and protects access to the secrets belonging to the application in the compartment. In servers, or peer-to-peer systems, trusted applications can talk to each other, whether they are in other compartments on the same platform or in compartments in other platforms. One important feature of this type of processing is that it prevents even the platform's administrator from violating the privacy of an application and data.

It is an object of the present invention to facilitate the use of protected processes in trusted platforms and, in particular, the release of keys to such processes. However, the present invention has wider application and is not to be limited in scope by the foregoing objective.

Summary of the Invention

The present invention is based in part on the observation that previous platform history is irrelevant for software provided that all traces of previous software have been unloaded or

existing software is benign (such as a protected compartment OS). In these cases, the operation of software is unaffected by software that previously executed on the platform. Software implementing a process may be considered to be "protected software", and the process a "protected process", when a mechanism expected to resist subversion provides a benign environment for that software/process to execute. That mechanism may, of course, itself be a protected process. The decision to release secrets for use by software can therefore be made purely on the basis of knowing that the particular software about to be executed will be protected software. So, if a TPM "knows" that protected software is about to be started, the TPM can safely release the secrets for that protected software without knowing the history of previously-executed software as represented, for example, by PCR values.

In the context of the TCPA architecture, a primary aspect of the present invention is concerned with arranging for secrets associated with a protected process to be released to the process by the TPM when the latter has received assurance that it is safe to do so. In a preferred embodiment, this involves the use of a "dynamic root key" that is associated with the protected process to be run, the key itself forming part of the key hierarchy stored in Protected Storage. The dynamic root key will generally form the root of a hierarchy of objects associated with the protected process, with the cryptographic use of the key and the cryptographic protection processes of this hierarchy being carried out either by the TPM or by the protected process. The TPM makes the dynamic root key available for use only upon authorization by a trustable source (for example, a hardware root-of-trust or another protected process such as a protected compartment OS) that is responsible for ensuring that the process associated with the dynamic root key is protected (which may simply be because the protected process is the only process executing). The TPM uses any appropriate means, physical or virtual, to verify that the authorization came from such a trustable source. Preferably, the authorisation required by the TPM before making the dynamic root key available, is a digest of the protected process.

Where the protected-process hierarchy based on the dynamic root key is to be processed by the TPM, when the protected process is run (or about to be run), the associated dynamic root key is installed in the TPM to act as the root of a hierarchy of (external) data objects

instead of the SRK. Access to parts of the key hierarchy that require ascent from the dynamic root key is prohibited.

Where the protected-process hierarchy based on the dynamic root key is to be processed by the protected process itself, when the protected process is run (or about to be run) the dynamic root key is released to the protected process.

Although the present invention has been outlined above in the context of the TCPA architecture, it is of broader application.

More particularly, according to one aspect of the present invention, there is provided a method of managing an hierarchy of nodes manipulated by processing apparatus, the method comprising a step of permitting access to a particular node of the hierarchy only after receiving a reliable indication that a mechanism expected to resist subversion will attempt to enforce appropriate access restrictions on that node and any descendent nodes.

In a preferred embodiment of this method, the aforesaid mechanism is a protected process executing in a benign operating environment within the apparatus, the method further comprising using a trusted source to establish or initiate establishment of the mechanism and to generate said reliable indication accordingly.

According to another aspect of the present invention, there is provided processing apparatus for managing an hierarchy of nodes, the apparatus comprising an access-control arrangement for permitting access to a particular node of the hierarchy only upon receiving a reliable indication that a mechanism expected to resist subversion will attempt to enforce appropriate access restrictions on that node and any descendent nodes.

According to yet another aspect of the present invention, there is provided processing apparatus comprising a key-handling unit for handling a tree-structured hierarchy in which each non-leaf node comprises a key used to encrypt the or each of its child nodes, the hierarchy including, below its top level, a node comprising a particular key associated with a protected process executable by the processing apparatus; the key-handling unit being

arranged to make said particular key available for use in relation to the protected process upon receipt both of authorisation to do so and an indication that the authorisation is provided by a trusted source that is arranged to provide this authorisation, and to initiate or permit execution of said protected process, only after verifying the presence of a benign operating environment within the apparatus for said protected process.

According to a further aspect of the present invention, there is provided processing apparatus comprising a key-handling unit for handling a tree-structured key hierarchy, the key-handling unit being arranged to treat a selected node of the hierarchy as the current root node such that those parts of the hierarchy that can only be reached by ascent from the current root node are inaccessible, the key-handling unit including an arrangement for changing the node of the hierarchy serving as said current root node.

According to a still further aspect of the present invention, there is provided a tree-structured key hierarchy with multiple nodes serving as root nodes dividing the hierarchy into different parts only accessible from corresponding root nodes.

Brief Description of the Drawings

Embodiments of the invention will now be described, by way of non-limiting example, with reference to the accompanying diagrammatic drawings, in which:

- **Figure 1** is a diagram of key hierarchy associated with a Trusted Platform Module;
- **Figure 2** is a diagram indicating the contents of a dynamic root key object of the Figure 1 key hierarchy;
- **Figure 3** is a diagram illustrating trusted platform elements involved in starting a protected process; and
- **Figure 4** is a diagram illustrating certain stages in the activation of a dynamic root key associated with the Figure 3 protected process.

Best Mode of Carrying Out the Invention

Figure 1 illustrates a trusted Platform Module (TPM) 10 with its normal Protected Storage data-object hierarchy 12 (also referred to below as a key hierarchy). The TPM's Storage

Root Key (SRK) 11 resides permanently inside the TPM 10. The SRK 11 is used to encrypt ("wrap") keys K1-1, K1-2, K1-3 etc. that form the next level of the hierarchy. Key K1-1, which in this case is preferably a non-migratable key, itself wraps further keys K2-1, K2-2, etc. The hatched outer annulus around each key in the Figure 1 key hierarchy 12 is a graphical indication that each key is wrapped (encrypted). A key in the hierarchy 12 can only be decrypted by the TPM 10 upon presentation to the latter of authorizations in respect of the ancestor keys in the hierarchy.

In the present example, Key K2-1 is a "dynamic root key object" 16. The dynamic root key 16 can be the child of any node in the key hierarchy 12; for example, the dynamic root key 16 could be a child of the SRK 11 rather than of key K1-1 as illustrated. As will be described below, the dynamic root key 16 acts as the root of a hierarchy of (external) data objects instead of the SRK, in respect of an associated protected process, whether the hierarchy belonging to the protected process is manipulated by the TPM or by the protected process.

The standard TCPA definition of a key is:

```
typedef struct tdTCPA_KEY{
        TCPA_VERSION ver;
        TCPA_KEY_USAGE keyUsage;
        TCPA_KEY_FLAGS keyFlags;
        TCPA_AUTH_DATA_USAGE authDataUsage;
        TCPA_KEY_PARMS algorithmParms;
        UINT32 PCRInfoSize;
        BYTE* PCRInfo;
        TCPA_STORE_PUBKEY    pubKey;
        UINT32 encSize;
        [size_is(encData)] BYTE* encData;
        } TCPA_KEY;
```

In fact, only the data in "encData" is encrypted (wrapped) by the key above in the key hierarchy, the other data being in cleartext (though any changes are detectable as a digest of that data forms part of the encrypted data).

The keyFlags variable is a structure that indicates Boolean properties of the key, currently redirection, migratable, and volatileKey.

In order to support dynamic root keys, according to the present embodiment, a new key flag DRK (dynamicRootKey) is added to KeyFlags. If the TPM 10 receives a "create key" command with a TCPA_KEY structure where the DRK flag is set, the TPM 10 automatically creates a dynamic root key without any change to the existing key creation functionality of the TPM.

Figure 2 illustrates the data structure of a dynamic root key, such as key 16, created by the TPM 10; as can be seen, the keyflags data 18 includes the DRK flag 19 which is in its 'set' state. The dynamic root key 16 also includes an authorisation value 17 which forms part of the encrypted data in "encData"; in the present case where the key 16 is a dynamic root key, the authorisation value 17 is the digest of a protected process (that is, a process that either protects itself, or is protected by another entity, from subversion, and attempts to enforce benign treatment of data, including enforcing appropriate access restrictions). The digest is created by processing with a hash algorithm the digital data that represents the protected process.

Rather than the TPM 10 creating a dynamic root key on the basis of the state of the DRK flag in a TCPA_KEY structure associated with a "create key" command, a separate flag could be added to the command itself to indicate that the new key is a dynamic root key.

Whenever the TPM loads a key for which the DRK flag 19 is set, it knows that the key is a dynamic root key and proceeds accordingly, as described below.

Figure 3 illustrates the trusted platform elements involved in starting a protected process 25 such as may be formed by a secure-compartment OS. The TPM 10 of the trusted platform is shown in its condition prior to the activation of the protected process 25 with its SRK 11 forming the root of the available key hierarchy 12 held in Protected Storage 23 that is physically stored in normal memory 22.

A Root of Trust (RT) 20 is responsible for activating the protected process 25 by initiating or permitting its execution by the platform's main processor 27 and by causing the TPM 10 to unlock the dynamic root key and enable its use, for example, to access keys that depend from it in the key hierarchy or to wrap and unwrap data presented to the TPM. The RT 20 is analogous to the RTM of a trusted platform and may, for example, be a hardware device (either part of the platform or dockable with it) or the platform as a whole running trusted software. The RT 20 is able to communicate with the TPM 10 in a manner that enables the TPM to believe that the communication came from the RT 20 (for example, the communication can be passed over a dedicated virtual or physical channel 21 or a trustable authentication process is used).

The various stages involved in the installation of the dynamic root key 16 (and any dependent object hierarchy) that is associated with the protected process 25 are described below with certain of these stages being illustrated in Figure 4.

1. At switch-on of the trusted platform, the TPM 10 (always) has the SRK 11 at the root of the available key hierarchy (see Figure 4).
2. At some point, the RT 20 determines that the protected process 25 associated with the dynamic root key 16 is the next process to execute and either has exclusive access to the TPM 10 (because the RT 20 has, for example, cleared all other processes from memory), or any existing protected processes will not abuse information obtained from the TPM (for example, the RT 20 may itself be a secure-compartment OS wishing to start process 25 in a compartment).
3. The RT 20 computes a digest of the protected process 25.
4. The key object K1-1 is loaded (using TPM_Loadkey) into the TPM 10 with authorisation to use the SRK 11; the load command and the related authorisation may come from the RT 20 or another element of the platform triggered by the RT 20.
5. The TPM 10 decrypts the key object KI-1 using the SRK's private key and obtains the key inside the K1 key object.
6. The key object K2-1 (the dynamic root key object 16) is loaded into the TPM 10

with authorisation to use the unwrapped key K1-1; again, the load command and the related authorisation may come from the RT 20 or another element of the platform triggered by the RT 20 .

7. The TPM 10 checks that unwrapped key K1-1 is a normal key by checking its DRK flag bit in the KeyFlags structure, and uses the unwrapped private key of key object K1-1 to decrypt key object K2-1 and obtain the key inside the dynamic root key object 16.

Step 8 or Step 9 is then carried out according to the conditions indicated below

8. **A.** If the dynamic root key object 16 was stored as a leaf-node (encrypted with a TPM_KEY_BIND key, for example) and intended to be revealed to the protected process (using a TPM_UnBind command, for example), the RT 20 presents the TPM 10 with authorisation to reveal the contents of object K2-1, this authorisation being the digest of the protected process 25 associated with the dynamic root key 16.

B. The TPM 10 notes that the key inside the key object K2-1 is a dynamic root key (by checking its DRK flag bit in the KeyFlags structure) and therefore verifies that the authorization came from the RT 20 (for example, by checking the channel on which the command was received), before revealing the key.

C. The protected process 25 can then use the revealed dynamic root key object 16 as the root of a key hierarchy manipulated directly by the protected process, for example.

9. **A.** If the dynamic root key object 16 has child objects that will be manipulated by the TPM (the dynamic root key object 16 is a TPM_KEY_BIND key or TPM_KEY_STORAGE key, for example), the RT 20 presents a TPM_ActivateDynamicRoot command to the TPM 10 with authorisation to use the key inside the key object K2-1, this authorisation being the digest of the protected process 25 associated with the dynamic root key 16 (see Figure 4).

B. The TPM 10 verifies that the TPM_ActivateDynamicRoot command came from the RT 20 (for example, by checking the channel on which the command was received), and that the key inside the key object K2-1 is a dynamic root key (by checking its DRK flag bit in the KeyFlags structure).

C. The TPM 10 deactivates, but does not unload or discard, the SRK 11 and uses

the dynamic root key 16 from the K2-1 key object as if it were the SRK (see Figure 4). In other words, the key 16 forms the root of a hierarchy of data objects, and its private key never leaves the TPM in plaintext form. When the TPM 10 loads the dynamic root key 16, the TPM unloads any existing keys including any previous dynamic root key (the SRK 11 is, however, retained in the TPM), and invalidates any keys that might have been cached outside the TPM 10 in encrypted form.

(As an alternative to the use of the TPM_ActivateDynamicRoot command as described above, the TPM could automatically replace the SRK by the DRK on recognizing that the DRK is a TPM_KEY_BIND key or TPM_KEY_STORAGE key and that authorisation came from the RT 20).

Thereafter, the dynamic root key 16 acts as the root of a hierarchy of (external) data objects instead of the SRK 11, in respect of the associated protected process 25, whether or not the processing of the hierarchy is done by the TPM or by the protected process 25.

If the SRK has been displaced by dynamic root key 16 (Step 9 above), one consequence is that it is no longer possible to go higher up the key hierarchy 12 than the dynamic root key 16 whilst the latter is activated. Once the DRK has replaced the SRK, it does not necessarily require further usage authorisation; furthermore, the DRK's child nodes do not necessarily require usage authorisation. This is because the loaded DRK and its child objects can be interpreted only while a safe environment exists so that generally there will be no need to require authorisation to use them. Hence the DRK may use the TCPA setting TPM_AUTH_NEVER once it has replaced the SRK, and the DRK's children may always use TPM_AUTH_NEVER. The TPM 10 continues to use the dynamic root key 16 instead of the SRK 11 until either a new dynamic root key is loaded and activated or until the SRK 11 is reloaded. The SRK 11 can be reloaded by either restarting the TPM 10, or by providing a new TPM command, TPM_InstallSRK (say). If the SRK has been displaced by dynamic root key 16, and the RTM or other protected process determines that the software environment is no longer benign, the RTM or other protected process preferably reload the SRK.

With the dynamic root key 16 installed, the protected process 25 can be run and can access the key 16 or data protected by the key 16 or a key below it in the key hierarchy.

Furthermore, as the protected process is now responsible for the trustworthiness of processes it runs, it is no longer necessary to use the seal and unseal functions described above to limit the initiation of processes to certain states of the platform. This is because previous history of the protected process is irrelevant because of the protections afforded to a protected process.

It will be appreciated that many variants are possible to the above described embodiments of the invention. Thus, for example, although in the foregoing, only one dynamic root key has been illustrated as part of the key hierarchy 12, it will be appreciated that multiple dynamic keys can be included in the hierarchy. Whether there is one or multiple dynamic root keys, the TPM 10 is preferably able to reliably indicate the root key that is currently active. This can be done, for example, by having the TPM 10 sign a value associated with the current root key, using a TPM identity key. The value that is signed could be the authorisation value of the dynamic root key but is, preferably, a digest of the authorisation value of the root key concerned.

It is also possible to arrange for a dynamic root key and its descendants to be manipulated by the TPM without the dynamic root key replacing the SRK. In one implementation, the TPM is arranged to store a "Dynamic Root Release" (DRR) indicator to indicate when the RT 20 has determined that it is safe to reveal the secrets belonging to a particular process – typically, the indicator would be a digest of the dynamic root key, the digest serving as an identifier of the root key. The secrets, stored in the protected storage hierarchy, that are descendants of the DRK are tagged with a root identifier (in the present example, the digest of the root key) to indicate that they can only be accessed when the TPM holds a corresponding DRR indicator. It is then the responsibility of the TPM to ensure that these secrets are revealed only when the TPM holds a DRR indicator that matches the process identifier stored with the secrets.

CLAIMS

1. A method of managing an hierarchy of nodes manipulated by processing apparatus, the method comprising a step of permitting access to a particular node of the hierarchy only after receiving a reliable indication that a mechanism expected to resist subversion will attempt to enforce appropriate access restrictions on that node and any descendent nodes.

2. A method according to claim 1, wherein said step is carried out in a tamper-resistant hardware module.

3. A method according to claim 1, wherein said mechanism is a protected process executing in a benign operating environment within the apparatus, the method further comprising using a trusted source to establish or initiate establishment of said mechanism and to generate said reliable indication accordingly.

4. A method according to claim 3, wherein each non-leaf node of said hierarchy comprises a key used to encrypt the or each of its child nodes, said particular node being a node, below the top level of the hierarchy, that comprises a particular key associated with said protected process, this key being made available for use in relation to the protected process upon said reliable indication being received.

5. A method according to claim 4, wherein said step is carried out in a tamper-resistant hardware module separate from said trusted source.

6. A method according to claim 4 or claim 5, wherein said particular key forms the root of an hierarchy of cryptographically-protected objects associated with the protected process.

7. A method according to claim 5, wherein said particular key is made available by revealing it unencrypted outside of said module to the protected process, the cryptographic use of said particular key and the cryptographic operations for accessing any of its descendant nodes, being carried out by said protected process outside of said module.

8. A method according to claim 5, wherein the cryptographic use of said particular key and the cryptographic operations for accessing any of its descendant nodes, are carried out within said module, the module responding to the trusted source providing said reliable indication in respect of said protected process to internally store a release indicator in respect of said particular node, descendants of said particular node being tagged with an identifier of said particular node, and the module only permitting access to a said descendant of said particular node when the identifier associated with the node concerned corresponds to a stored release indicator.

9. A method according to claim 5, wherein making said particular key available comprises installing it as the current operative root node of said tree-structure hierarchy such that those parts of the hierarchy that can only be reached by ascent from the current root node are inaccessible, the cryptographic use of said particular key and the cryptographic operations for accessing any of its descendent nodes, being carried out within said module.

10. A method according to any one of the preceding claims, wherein access to said particular node is further conditional upon presentation of an authorisation.

11. A method according to claim 10, wherein said authorisation is a digest of the protected process, the trusted source calculating this digest from the protected process code to be executed.

12. A method according to any one of claims 3 to 11, wherein said trusted source is a hardware root of trust.

13. A method according to any one of claims 3 to 11, wherein said trusted source is a protected compartment operating system executing on the apparatus.

14. A method according to any one of claims 5 to 13, wherein the tamper-resistant module holds, in unencrypted form the top-level node of said hierarchy, the other nodes of the hierarchy being stored in encrypted form separately from the key-handling unit when not being used.

15. A method according to any one of claims 5 to 14, wherein the tamper-resistant module is a Trusted Platform Module according to the TCPA architecture.

16. Processing apparatus for managing an hierarchy of nodes, the apparatus comprising an access-control arrangement for permitting access to a particular node of the hierarchy only upon receiving a reliable indication that a mechanism expected to resist subversion will attempt to enforce appropriate access restrictions on that node and any descendent nodes.

17. Apparatus according to claim 16, wherein the access-control arrangement is implemented in a tamper-resistant hardware module.

18. Apparatus according to claim 16, further comprising means for implementing said mechanism as a protected process executing in a benign operating environment within the apparatus, and a trusted source for initiating said mechanism and generating said reliable indication accordingly.

19. Apparatus according to claim 18, wherein the access control arrangement is provided by a key-handling unit and each non-leaf node of said hierarchy comprises a key used to encrypt the or each of its child nodes, said particular node being a node below the top level of the hierarchy that comprises a particular key associated with said protected process, the key-handling unit being arranged to make this key available for use in relation to the protected process upon said reliable indication being received.

20. Apparatus according to claim 19, wherein the key-handling unit takes the form of a tamper-resistant hardware module separate from said trusted source.

21. Apparatus according to claim 19 or claim 20, wherein said particular key is arranged to form the root of an hierarchy of cryptographically-protected objects associated with the protected process.

22. Apparatus according to claim 20, wherein the key-handling means is arranged to make said particular key available by releasing it unencrypted to the protected process, the cryptographic use of said particular key and the cryptographic operations for accessing any of its descendent nodes, being arranged to be carried out by said protected process when executing in the apparatus.

23. Apparatus according to claim 20, wherein the key-handling unit comprises:

- first means responsive to the trusted source providing said reliable indication in respect of said protected process to store a release indicator in respect of said particular node;
- second means for permitting access, within the key-handling unit, to a node only when the node concerned has an identifier indicating a relationship with a node for which a said release indicator has been stored by the first means;
- third means for carrying out cryptographic use of said particular key and cryptographic operations for accessing any of its descendent nodes.

24. Apparatus according to claim 20, wherein the key-handling means is arranged to make said particular key available by installing it as the current operative root node of said tree-structure hierarchy handled by the key-handling unit such that those parts of the hierarchy that can only be reached by ascent from the current root node are inaccessible, the cryptographic use of said particular key and the cryptographic operations for accessing any of its descendent nodes, being arranged to be carried out by the key-handling unit.

25. Apparatus according to any one of claims 16 to 24, wherein said authorisation is a digest of the protected process.

26. Apparatus according to claim 25, wherein said authorisation is a digest of the protected process, the trusted source being arranged to calculate this digest from the protected process code to be executed.

27. Apparatus according to any one of claims 18 to 26, wherein said trusted source is a hardware root of trust.

28. Apparatus according to any one of claims 18 to 26, wherein said trusted source is a protected compartment operating system arranged to execute on the apparatus.

29. Apparatus according to any one of claims 20 to 28, wherein the key-handling unit is arranged to hold, in unencrypted form the top-level node of said hierarchy, the key-handling unit being further arranged to store the other nodes of the hierarchy in encrypted form separately from the key-handling unit.

30. Apparatus according to any one of claims 20 to 29, wherein the key-handling unit is a Trusted Platform Module according to the TCPA architecture.

31. Processing apparatus comprising a key-handling unit for handling a tree-structured hierarchy in which each non-leaf node comprises a key used to encrypt the or each of its child nodes, the hierarchy including, below its top level, a node comprising a particular key associated with a protected process executable by the processing apparatus; the key-handling unit being arranged to make said particular key available for use in relation to the protected process upon receipt both of authorisation to do so and an indication that the authorisation is provided by a trusted source that is arranged to provide this authorisation, and to initiate or permit execution of said protected process, only after verifying the presence of a benign operating environment within the apparatus for said protected process.

32. Apparatus according to claim 31, further comprising said trusted source.

33. Apparatus comprising a key-handling unit for handling a tree-structured key hierarchy, the key-handling unit being arranged to treat a selected node of the hierarchy as the current root node such that those parts of the hierarchy that can only be reached by ascent from the current root node are inaccessible, the key-handling unit including an arrangement for changing the node of the hierarchy serving as said current root node.

34. Apparatus according to claim 33, wherein the arrangement for changing the current root node is enabled to do so only upon a predetermined set of at least one condition being met.

35. Apparatus according to claim 34, wherein at least one predetermined condition comprises the receipt of an authorisation value indicative of digital data.

36. Apparatus according to claim 35, wherein said authorisation value is a digest of a protected process associated with the node that is intended to be the new current root node

37. Apparatus according to claim 35 or claim 36, wherein at least one predetermined condition comprises that a protected process associated with the node that is intended to be the new current root node is about to be run by the apparatus.

38. Apparatus according to claim 37, wherein at least one predetermined condition comprises that any other currently-activated processes running on the apparatus are benign.

39. Apparatus according to any one of claims 34 to 37, wherein at least one predetermined condition comprises that the key-handling apparatus is requested to change the current root node by a root of trust of the apparatus.

40. Apparatus according to any one of claims 33 to 39, wherein the node at the head of the hierarchy as judged without regard to which node is the current root node, forms said current root node upon start of the apparatus.

41. Apparatus according to any one of claims 33 to 40, wherein the key-handling unit is arranged to hold the current root node internally in unencrypted form at least whilst it remains the current root node.

42. Apparatus according to any one of claims 33 to 41, wherein the key-handling unit is arranged always to hold the node at the head of the hierarchy, as judged without regard to which node is the current root node, internally in unencrypted form.

43. Apparatus according to any one of claims 33 to 41, wherein the key-handling unit is a Trusted Platform Module according to the TCPA architecture.

44. Apparatus according to any one of claims 33 to 43, wherein the key-handling unit is arranged to indicate the current root node by signing a value associated with the node using an identity key associated with the key-handling unit.

45. Apparatus according to claim 24 when dependent on claim 35 or claim 36, wherein said value associated with the current root node is the authorisation value associated with the node or a digest of that value.

46. Apparatus according to any one of claims 33 to 45, wherein the key-handling unit is so arranged that only a particular type of key node, herein a dynamic key node, can be used as the current root node in addition to the node at the head of the hierarchy as judged without regard to which node is the current root node.

47. Apparatus according to claim 46, wherein the key-handling apparatus is arranged, upon receipt of a corresponding command, to generate a dynamic root node as a node of said key hierarchy.

48. A tree-structured key hierarchy with multiple nodes serving as root nodes dividing the hierarchy into different parts only accessible from corresponding root nodes.

ABSTRACT

Method and Apparatus for Managing a Hierarchy of Nodes

Processing apparatus, such as a trusted platform, is provided with an access-control arrangement (10) for handling a tree-structured hierarchy such as a key hierarchy (12). The access-control arrangement (10) only permits access to a particular node (16) of the hierarchy upon receiving a reliable indication that a mechanism expected to resist subversion will attempt to enforce appropriate access restrictions on that node. Such a mechanism is, for example, a protected process (25) executing in a benign environment in the apparatus. The indication that the mechanism is in place is provided by a trusted source (20), such as a hardware root of trust responsible for initiating the mechanism. Access to the particular node (16) opens the way to revealing that node, and any descendants, to the protected process (25).

(Figure 3)

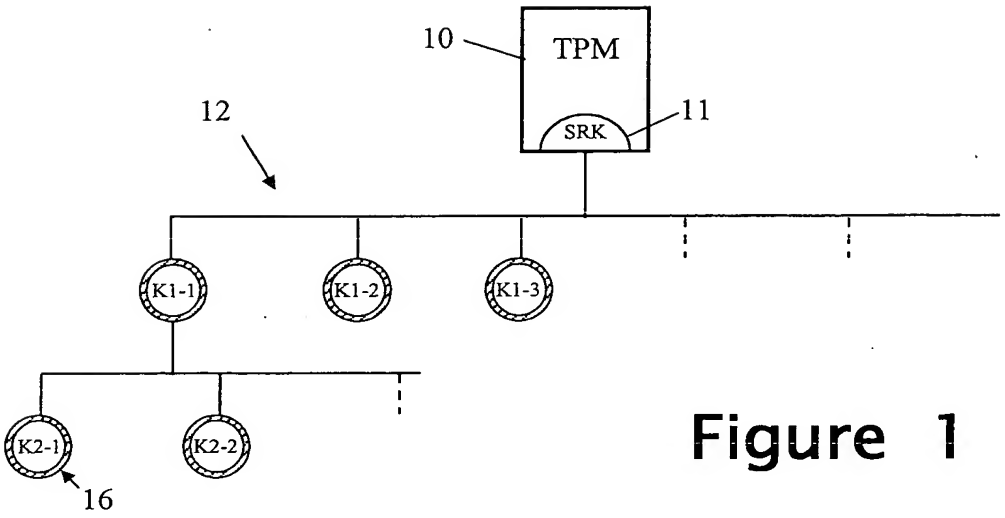


Figure 1

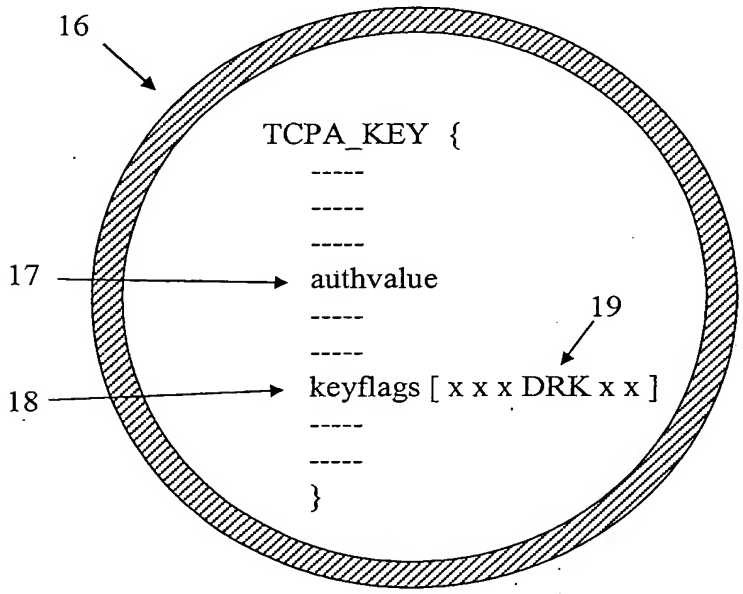


Figure 2

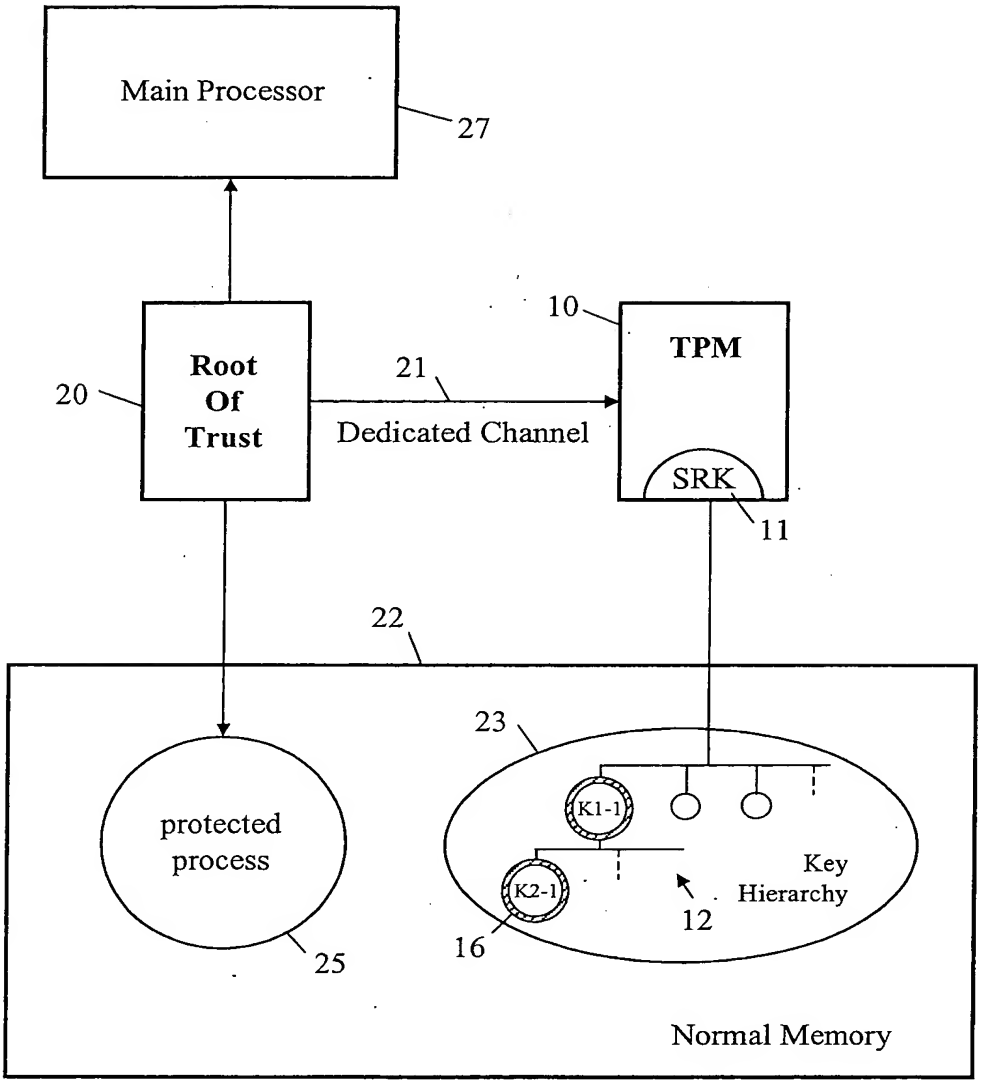

Main Processor
27
Root
Of
Trust
20
21
Dedicated Channel
10
TPM
SRK
11
22
23
protected
process
25
K1-1
K2-1
16
Key
Hierarchy
12
Normal Memory

Figure 3

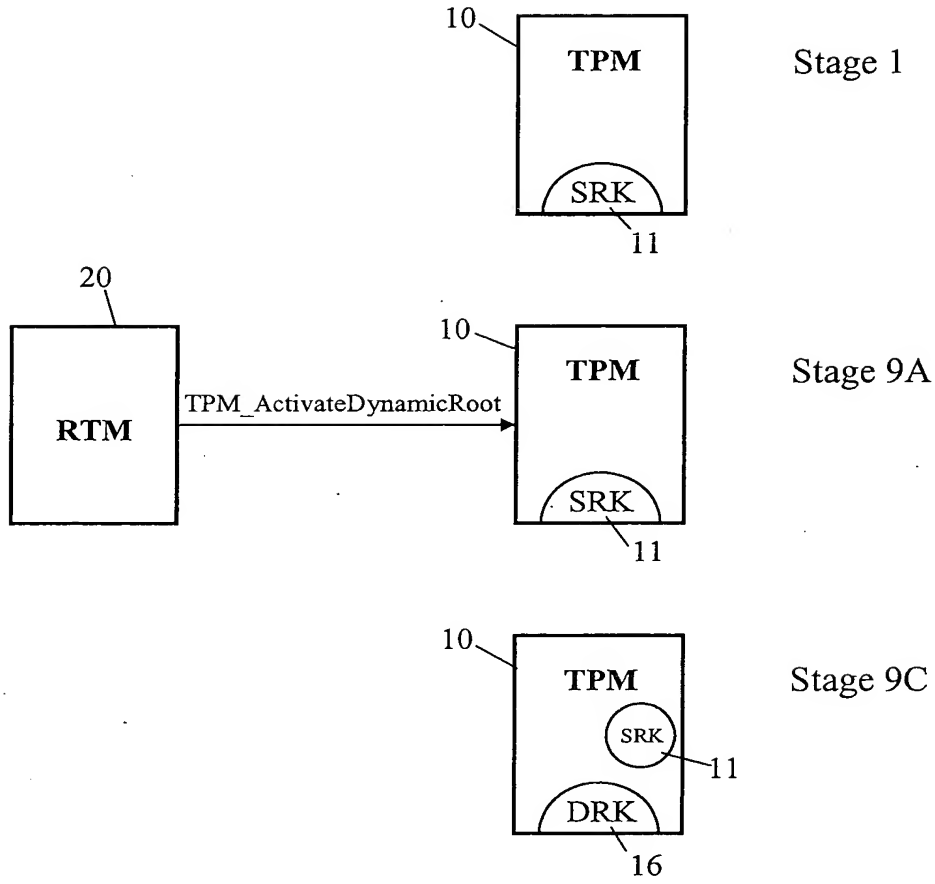

10
TPM
SRK
11
Stage 1
20
RTM
TPM_ActivateDynamicRoot
10
TPM
SRK
11
Stage 9A
10
TPM
SRK
11
DRK
16
Stage 9C

Figure 4